place of the Moon, and any error in the adopted value of the nutation practically disappears from the result. This point has been already dealt with by Airy in his *Reduction of the Greenwich Lunar Observations* (1831–1851), p. xxiv.

Hence the correction to be applied to Airy's value is the difference between Airy's value and Hill's value for the figure of the Earth Term or

$$+1''\cdot07 \sin \Omega$$

and not

$$+\cdot45 \sin \Omega$$

the value employed by Mr. Cowell.

By greater skill and ingenuity Mr. Cowell may be more successful than myself in dealing with the investigation of the corrections required by the lunar tables in the rather fragmentary manner he has adopted. I failed, and I fear that further experience will lead him to the same conclusion as myself—that no successful result can be expected without taking the problem up as a whole and simultaneously taking into consideration the inequalities of all kinds and periods.

Natal Observatory:
1904 *January* 21.

Photographic Chart of the Heavens to Argelander's scale $1^\circ = 20$ *mm., with special reference to the Milky Way.* By J. Franklin-Adams; *with description of Lenses and Mounts* by H. Dennis Taylor and Alfred Taylor.

Preliminary Notes by J. Franklin-Adams.

To Sir David Gill am I indebted for the suggestion of photographic research into the structure of the Milky Way. The tentative and experimental method by which the work has been carried out may be interesting in detail.

During the winter of 1897–8 Mr. Dennis Taylor, of Messrs. Cooke & Sons, was asked to design a 6-inch lens of short focus and considerable field-focus, $\frac{f}{4}$. During the autumn of 1898 the lens was temporarily mounted upon an 8-inch German equatorial, also by Cooke & Sons: it gave fair definition over a field, $20^\circ \times 20^\circ$ upon a plate 10 in. $\times$ 10 in., working with full aperture. This was in the observatory at Machrihanish House, Argyllshire, with the conveniences of exact time, electric current, developing rooms, and workshops. After working for a

year upon various problems of diffusion of focus, speed, diaphragm, exposure, &c., I had the good fortune to receive a month's visit—in January 1900—from Professor Barnard, who had heard of the lens, and had travelled to Machrihanish to examine it. After scrutinising the results to date he worked for ten nights at experiments of his own, especially comparing the lens with his celebrated Petzval as to rapidity. For this purpose we made a rough camera for his lens and placed the two side by side.

We then journeyed together to York, taking with us a set of our photographs—upon patent plate—mostly of *Orion*, as giving stars of many magnitudes, and two important nebulæ. After discussion with Mr. Dennis Taylor it was decided to recompute curves and alter the ratio to $\frac{f}{4 \cdot 5}$, thus reducing the field, and make a new experimental lens of 4 in. diameter upon these new lines; if successful the 6 in. to be refigured in accordance with experience gained in making the 4 in.

This 4-in. lens was finished in time to take to Santa Pola in Spain with the Scottish Eclipse (1900 May 28) Expedition, to which I was attached; some photographs of the corona were taken with it, and, after the eclipse, also some of stars, *Jupiter*, and the Moon. The results were excellent, the plates were taken to Mr. Dennis Taylor, and the re-figuring of the 6 in. put in hand.

The experiments with the 6-in. lens in its original state were now repeated with the lens in its altered form, and were so successful that a 10-in. lens was ordered, a detailed description of which, by Mr. Dennis Taylor, is appended to these notes. I would wish to say that I alone am responsible for the choice between a field of $12° \times 12°$ with good images everywhere, or a field of $15° \times 15°$ with the images at the corners only "fair." I chose the latter partly because it would reduce the magnitude of the undertaking before me and partly because 120 of the 206 plates would each cover exactly an hour of R.A.

On receiving the 10-in. lens I found that its weight in brass and aluminium mount was about 100lb.; it was mounted temporarily for experimental work on the 8-inch equatorial with 4-inch guider, and prints were sent to Professor Kapteyn, of Gröningen, and, in consideration of his admirable work on the Milky Way, to M. Easton, of Brussels. Professor Kapteyn gave much kindly advice, criticism, and approval of the work. In one square (equatorial) degree in *Cygnus* he counted 670 stars—exposure 2 hours. This gives in a space $2° \times 2°$ more stars than are visible to the naked eye in a hemisphere. The exposure adopted was 2 hours 20 minutes for British stations, 2 hours for southern stations.

Mount.—After visits to every important observatory in Great Britain and to several on the Continent—and I would especially acknowledge great kindness from Dr. Wolf, of Heidelberg, and Professor Becker, of Glasgow, and from all the staff of

Potsdam—I decided upon an English mount with modifications. A description of this, by Mr. Alfred Taylor, of Messrs. Cooke & Sons, follows this paper. I will only mention the points for which I am specially responsible. (*a*) Two 6-in. guiding telescopes instead of one, (*b*) a new eyepiece carrier for rapid finding of guiding stars and fine adjustment when found. As the instrument will in charting always be set to an arbitrary point, *e.g.* 0^h–60°, there may not be, and as a fact there generally is not, a catalogue star in the field. When only small stars are available the colour decides which shall be used. (*c*) Against much good advice I chose a circle instead of a sector, and a circle for slow motion in declination, driving both slow motions by motors. I do not know whether I can lay claim to being the first to use motors for these controls, but they have been successfully used by me for some years. Especially is it useful in alteration of declination necessitated by the varying refraction, the touching of the telescope in second-controlled clocks often causing a dropped second. With the luck of varying atmospheric densities happening at the right time and in the right direction, some plates have been run by the Repsold clock for the two hours without hand interference. (*d*) An arrangement by which either of the guiding telescopes can be thrown 10 degrees or less away from the direction of the camera. By this means, photographs of comets can be guided by the head in the corner of the plate, thus utilising the whole of the plate—15 to 23 degrees—for the tail. I am indebted for this suggestion to my friend Professor Barnard. (*e*) I made a full-sized schematic model of the mount and a small model of the house, which latter Messrs. Cooke developed and copied.

Expedition to the Cape.—In 1903 June my assistant, Mr. G. N. Kennedy, sailed for Cape Town, taking with him the complete instrument and its house. I followed five weeks later, found the house erected and the piers built, and within a fortnight of arrival all was ready for final adjustment of mount and for focussing and centering of the lenses and réseaus. The réseau for the 10 in. was the only exception to all being in order: it had been engraved and packed whilst I was ill in bed, and unfortunately some lines, through not being deeply engraved, are missing upon the early prints 19^h to 23^h, after which a new réseau arrived. It is immaterial, however, as transparent scales are to be used with the proposed atlas, with the degrees of declination marked exactly in hyperbolas or approximately in circles as may be decided; whilst for counting stars on the negatives the measuring machine can be adapted to bridge the missing lines. There were personal reasons why it was convenient to finish the charting of the southern hemisphere first, but the following extract from M. Easton's work, *Distribution de la Lumière Galactique*, is perhaps sufficient without these :

"La distribution des grandeurs stellaires trouvée par Kapteyn n'est pas en contradiction avec la supposition que nous avons faite.

Ce serait un travail intéressant de pousser plus loin cette comparaison, mais je n'ose décider si les données fournies par la présente étude ne sont pas trop incomplètes, presque rien n'étant connu sur la distribution des étoiles dans l'hémisphère austral, ni si elles comportent la précision nécessaire pour des recherches pareilles."

The equatorial plates were compared and identified with Argelander and Schönfeld, but comparison with Gould for the plates south of these was hopeless. For this reason and for the count of the lucid stars I fell in with Sir David Gill's suggestion to take also "triangle plates" with the 10 in. lens. The working scheme is therefore as follows :

91	plates from	+7° 30′ to +90°
91	" "	−7° 30′ to −90°
24	" "	+7° 30′ to −7° 30′
206	" "	15 in. × 15 in., 2 hours.
206	" "	15 in. × 15 in., 7 minutes ; 3 times in triangle form.
206	" "	12 in. × 10 in., 2 hours.
618		
618	transparencies.	
1,236	plates.	

The scheme for the Cape includes :

91 + 24 = 115	plates	15 in. × 15 in., 2 hours'	exposure.
115	"	15 in. × 15 in., 7 mins. 3 times	"
115	"	12 in. × 10 in., 2 hours'	"
345			
345	transparencies.		
Total 690	plates.		

Besides these there will be about fifty duplicates, and some picture plates of long exposures—four to five hours.

Each 15 in. × 15 in. is compared with its fellow triangle plate, and with the 12 in. × 10 in. of the same region.

When the 10-inch proved such a success, I at once communicated with Messrs. Cooke as to a duplicate, but, alas ! the melting from which my discs were made had all been used, and another melting could not be depended upon to give the same focus and therefore the same scale. I decided therefore to mount the 6-inch for duplicate plates. If I had been able to arrange for twin lenses of 10 in. I should not have required the transparencies for sending home in a separate steamer, and should

x x

have saved considerable time in being obliged to take several exposures of 15 in. × 15 in. and 12 in. × 10 in. alone for spoiled plates. Duplicate plates are absolutely necessary for identifying nebulæ, perhaps a nova, meteors, faults of réseau, or blemishes in film.

The scale of the 10-in. lens is 20 mm. = 1° on the equator
" " 6-in. " 11 mm. = 1° " "
this latter only approximately.

The plates of the 10 in. are 15 in. × 15 in. (approximately $0^{m}\cdot381$)
" " 6 in. " 15 in. × 10 in., of which only 10 in. × 10 in. will be used, and these will give a good overlap, which the large plates do not.

Both lenses are worked at full aperture.

The good and fair field on each plate is 15° × 15°.

The developer throughout is amidol; at some important observatories the labour of development is much reduced by *time* and not by *visual* development. The developer is applied at a certain strength and temperature for a given number of minutes. The plates under consideration have been developed visually. When safe, ample, and equally distributed light is not available this time system has much to recommend it, but it would probably mean a fresh developer for each plate.

The chart plates are Cadett Lightning; the triangle plates are Imperial flash-light; the transparencies are ordinary plates of both makers.

The driving of the instrument in R.A. by a Repsold clock is a great success. Some plates have been exposed for the two hours without once touching the R.A. motor, but as a rule the varying refraction in so long an exposure and so large a field makes a slight alteration, say three or four times an hour, both in R.A. and decl. advisable. It is quite remarkable that with the varying driving power required in different positions—owing again to the long exposure—this clock drives steadily on with hardly any variation of pace, whereas a Russell Mouse-control clock would stop. If, too, as occasionally happens, a little grit in the driving worm or some other unknown cause should slow down the motion, it is only a slight slow down, and not the miss of a whole second of time as in controlled clocks. The circle instead of sector—a particularly fine one—is a great convenience.

I have been asked why I have deviated from my first intention of photographing the Milky Way only. The reply is (*a*) that the ramifications and extensions of the Milky Way are so undefined that it seemed advisable to chart all regions; (*b*) that as nine months' work, approximately, would be required for the Milky Way alone the whole of the hemisphere could be charted in the same time, although with, of course, more work.

Many points—*e.g.* length of exposures—have been decided because of their bearing on the Milky Way. The intention is to publish the work as an atlas in triplicate *form*: (1) the

15 in. × 15 in.; (2) the 12 in. × 10 in. as a check upon false nebulæ and false stars, both upon paper with gelatine surface; (3) the triangle plates upon writing paper, and for this reason, besides being a second check upon faults in film, they should be a valuable help to workers in special branches of stellar work. A double-star worker, for instance, could number all known double stars according to the several catalogues, S 1004, B 191, I 34, and so on. The same with variables, nebulæ, &c. The expense of such publication would, however, be so serious that I must wait until better times in South Africa for a millionaire to help me with the cash, and in the meantime I propose to print photographically about five copies for public institutions. Any printing, whether photographic or mechanical, will, however, be absolutely *untouched*, and will show all faults, scratches, &c. It seems to me that a single interference of only one spot in a thousand plates would cast a doubt upon the pictorial integrity of any given region.

To record my sense of thanks to Sir David Gill for his kindness in allotting me a splendid site, and for his ever-kindly help and advice, is a great pleasure. Each one of the staff of the Royal Observatory at Cape Town has done his best to render the work as easy and as agreeable as possible.

Professor Barnard has had a 10-inch lens and mount made in America, the lens by Brashear and the mount by Warner & Swasey. It will be interesting to compare the two instruments. I have reason to think that of the two his will work upon a rather smaller field, and that his lens will be more rapid. I do not know the direction in which he proposes to work, nor do I know the scale.

In these days of many observatories in Great Britain, understaffed though they may be; of many more on the continent of Europe, supplied liberally with Government funds; and of still more in America, where wealthy citizens give large sums to build, house, and endow instruments of record size, it may seem difficult to find an unoccupied field of research. That there are such fields, however, is certain, and among them it seems likely that many will be found in that domain which contains the secrets of the structure of the universe.

Description of the Lenses. By H. Dennis Taylor.

Mr. Franklin-Adams has asked me to give a condensed description of his 10-inch aperture Cooke lens, with a short explanation of the theory of its construction.

It is a particular case of the Cooke photographic lens modified for celestial purposes. The essential aim of the Cooke lenses was to obtain a flat image substantially free from astigmatism, besides being rectilinear and achromatic, with the minimum number of lenses possible. This result was obtained with only three simple lenses, two outer positive lenses and an inner